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Advances In Global Aerosol Modeling Applications Through Assimilation of Satellite-Based Lidar Measurements

James Campbell (1), Edward Hyer (1), Jianglong Zhang (2), Jeffrey Reid (3), Douglas Westphal (3), Peng Xian (3), and Mark Vaughan (4)

(1) University Corporation for Atmospheric Research Visiting Scientist Programs, c/o Naval Research Laboratory, Monterey, California, USA (*jamesc@ucar.edu/+1 831 656 4769), (2) University of North Dakota Atmospheric Sciences Program, Grand Forks, North Dakota, USA, (3) Naval Research Laboratory, Monterey, California, USA, (4) NASA Langley Research Center, Hampton Roads, Virgina, USA

Modeling the instantaneous three-dimensional aerosol field and its downwind transport represents an endeavor with many practical benefits foreseeable to air quality, aviation, military and science agencies. The recent proliferation of multi-spectral active and passive satellite-based instruments measuring aerosol physical properties has served as an opportunity to develop and refine the techniques necessary to make such numerical modeling applications possible. Spurred by high-resolution global mapping of aerosol source regions, and combined with novel multivariate data assimilation techniques designed to consider these new data streams, operational forecasts of visibility and aerosol optical depths are now available in near real-time[1].

Active satellite-based aerosol profiling, accomplished using lidar instruments, represents a critical element for accurate analysis and transport modeling. Aerosol source functions, alone, can be limited in representing the macrophysical structure of injection scenarios within a model. Two-dimensional variational (2D-VAR; x, y) assimilation of aerosol optical depth from passive satellite observations significantly improves the analysis of the initial state. However, this procedure can not fully compensate for any potential vertical redistribution of mass required at the innovation step. The expense of an inaccurate vertical analysis of aerosol structure is corresponding errors downwind, since trajectory paths within successive forecast runs will likely diverge with height.

In this paper, the application of a newly-designed system for 3D-VAR (x, y, z) assimilation of vertical aerosol extinction profiles derived from elastic-scattering lidar measurements is described [*Campbell et al.*, 2009]. Performance is evaluated for use with the U. S. Navy Aerosol Analysis and Prediction System (NAAPS) by assimilating NASA/CNES satellite-borne Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) 0.532 μm measurements [*Winker et al.*, 2009]. Inversion retrievals of aerosol extinction are performed for one-degree latitudinal averages of CALIOP backscatter signal (thus matching the horizontal resolution of NAAPS) by constraining total column transmission using the model estimate of AOD at the corresponding wavelength. As such, this system serves as a post-processing module predicated on newly-operational NAAPS aerosol analysis fields that feature 2D-VAR assimilation of NASA Moderate Resolution Infrared Spectroradiometer (MODIS) AOD observations [*Zhang and Reid*, 2006; *Zhang et al.*, 2008].

We describe the influence of 3D-VAR assimilation on NAAPS analyses and forecasts by considering the physical evolution of Saharan dust plumes during their advection across the tropical Atlantic basin. Steps taken towards characterizing spatial covariance parameters that broaden the horizontal influence of information obtained along the limited lidar orbital swath are discussed. This latter context is critical when comparing the efficacy and impact of 3D-VAR assimilation with that of 2D-VAR procedures, which benefit from passive observations with a relatively wide field-of-view and, therefore, greater/more routine global coverage. With multiple satellite-lidar projects either pending launch or in design stages, including the dual ESA missions (AEOLUS and EarthCARE), we describe the potential impact of future 3D-VAR assimilation activities; both for NAAPS forecast capabilities, and the anticipated growth in aerosol transport modeling efforts at federal and cooperative global agencies worldwide.

[1] http://www.nrlmry.navy.mil/aerosol/

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